Operating characteristics of the Martin resil-
ient wheel spoke. (Report No. 40.) J. C.
Little and R. H. Neill. American Steel & Wire
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Operating Characteristics of the
Martin Resilient Wheel Spoke

Report No. 40 October 22, 1943

INTRODUCTION

This report deals with tests conducted on spokes from a Martin Resilient Wheel. This wheel was invented by Capt. J.V. Martin and the investigation was requested by the Office of Scientific Research and Developement. The Martin Wheel consists of a number of molded rubber spokes mounted radially between a hub and an outer rim. The spokes are so proportioned that when the wheel is assembled, all the spokes are in tension. Thus the weight of a vehicle on this wheel causes the spokes at the top of the wheel to stretch farther, at the same time causing the bottom spokes to relax; the resiliency of the wheel depending on the elasticity of the rubber spokes.

PURPOSE

The purpose of this investigation was as follows:

a) To determine the relative load-deflection characteristics of rubber and neoprene spokes.
b) To determine the lateral stability of the Martin spoke.
c) To repeatedly deflect rubber and neoprene spokes in a manner simulating operating conditions and observe:
   1. Amount of temporary and permanent elongation.
   2. Surface temperatures generated.

PROCEDURE

a) The method of loading the spokes for determining axial load-deflection characteristics is shown in Figures VIII, IX, X, and XI. White lines were ruled on the spokes to facilitate observation of the manner of deflection.
b) In order to determine the lateral stability of the Martin spoke, two rubber spokes were assembled in a special fixture as shown in Figure XII. An axial load of 100 pounds was exerted on the spokes which were then locked in this extended position. The lateral loading was applied to the spokes as shown in Figure XIII. This procedure was repeated for axial preloads of 150 and 200 pounds.
c) The repeated-deflection tests were carried out in the testing machine shown in Figure XIV. The upper beam is fixed; the center beam reciprocates vertically. One rubber and one neoprene spoke were mounted in the machine with an initial extension of 5/8 inch. The motion of the center beam was adjusted to produce an additional extension of 1 inch. The machine was run at a speed of 600 cycles per minute, corresponding to a wheel speed of 50 miles per hour. The free length of each spoke was measured at the start of the test run, and at frequent intervals during the test. Measurements were made immediately after removing the spokes from the machine and also after varying periods of time during which the spokes were allowed to recover as much of the temporary elongation as possible.

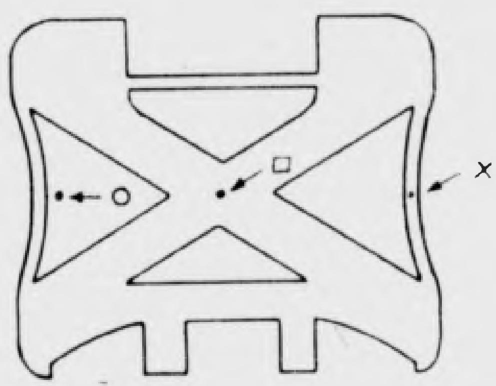
Measurements of surface temperatures generated during this test were made by attaching thermocouples to the spokes as shown in Figure XV. All the thermocouples were connected to a selector switch, facilitating the rapid measurement of temperatures at frequent intervals. Temperatures were measured during the first 50,000 cycles of continuous operation, after which the spokes were removed for length measurements. They were then put back in the machine and the maximum temperatures attained during each subsequent 50,000 cycle run were recorded, until the temperatures became constant or decreased.

This procedure was repeated for another rubber and neoprene spoke using 7/8 inch initial extension and an operating extension of 1 inch.

RESULTS

a) The results of the axial load-deflection tests are plotted in Figure I, for one rubber and one neoprene spoke.
b) Figure II presents the lateral load-deflection characteristics of a pair of rubber spokes under initial axial tensions of 100, 150, and 200 pounds.
c) The amount of temporary and permanent elongation caused by repeated deflection is presented for each spoke tested in Figures III, IV, V, and VI. In each case the diagonal lines indicate the amount of temporary elongation or stretch, while the vertical lines represent the recovery of this elongation while the spokes were unloaded for varying periods of time.

In Figure VII the surface temperatures at three points are plotted versus number of cycles for each spoke tested. The symbols on the curves refer to the locations of the thermocouple junctions which are shown in the following sketch:



The repeated deflection tests were run for about 3,000,000 cycles. Only one failure of a spoke was observed; this was a neoprene spoke operated with an initial extension of 5/8 inch. The location of the failure is shown by the arrow in Figure X. The crack appeared after 200,000 cycles, and did not enlarge any after about 500,000 cycles.

DISCUSSION

a) It is apparent that in order to maintain the same load-elongation rate for rubber and neoprene spokes, the latter must have a larger cross-section for increased stiffness.

b) The curves in Figure II reveal the interesting fact that the lateral rate of the pair of rubber spokes decreases with increasing axial tension. This is probably due to the fact that, as shown in Figure I, the axial load rate, or slope is variable. Thus, when the pair of spokes is subjected to an initial tension of 100 pounds, and then is deflected laterally (which in effect produces additional tension in the spokes) the rate is higher--that is, the spokes are working in the left-hand portion of the curve in FigureI--than when the initial tension is 200 pounds, in which case the spokes are working in the right-hand portion of the curve where the rate is lower.

c) The repeated axial-deflection tests indicate that failures of the spokes are not a problem. However, the continual stretching of the spokes in service may result in removing all the tension which the spokes had when originally assembled in a wheel, particularly if the amount of initial tension is large.

Neoprene spokes clearly stretch more than rubber under the same conditions of equal repeated extension. There appears to be little difference in heat generation between rubber and neoprene. However, it must be remembered that in the above tests, the rubber and neoprene spokes were deflected equal amounts, while the resulting loads were much less on the neoprene spokes.

J.C. Little
R.H. Neill

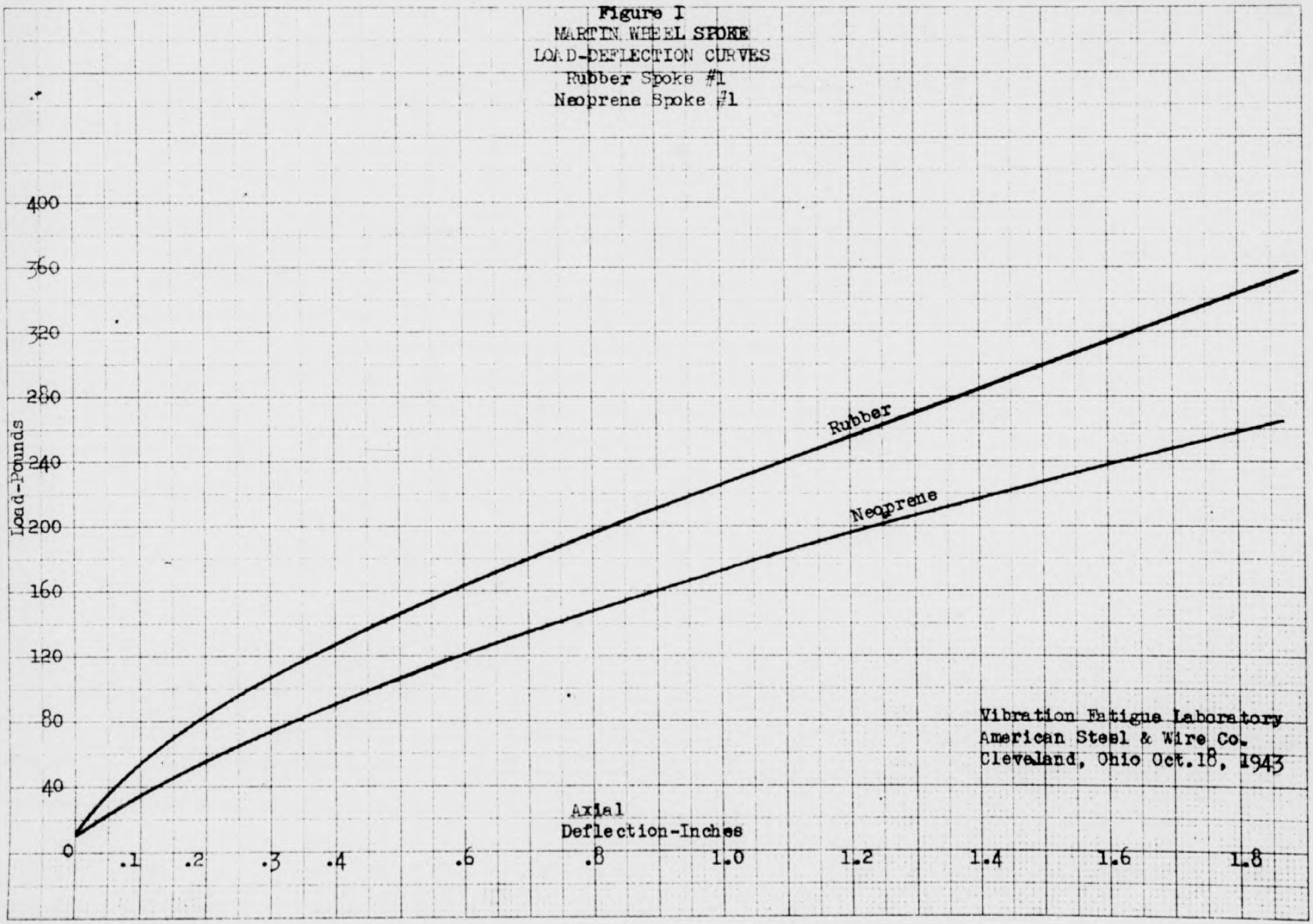


Figure I
MARTIN WHEEL SPOKE
LOAD-DEFLECTION CURVES
Rubber Spoke #1
Neoprene Spoke #1
Load-Pounds
400
360
320
280
240
200
160
120
80
40
0
.1
.2
.3
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
Axial
Deflection-Inches
Rubber
Neoprene
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Cleveland, Ohio Oct.18, 1943

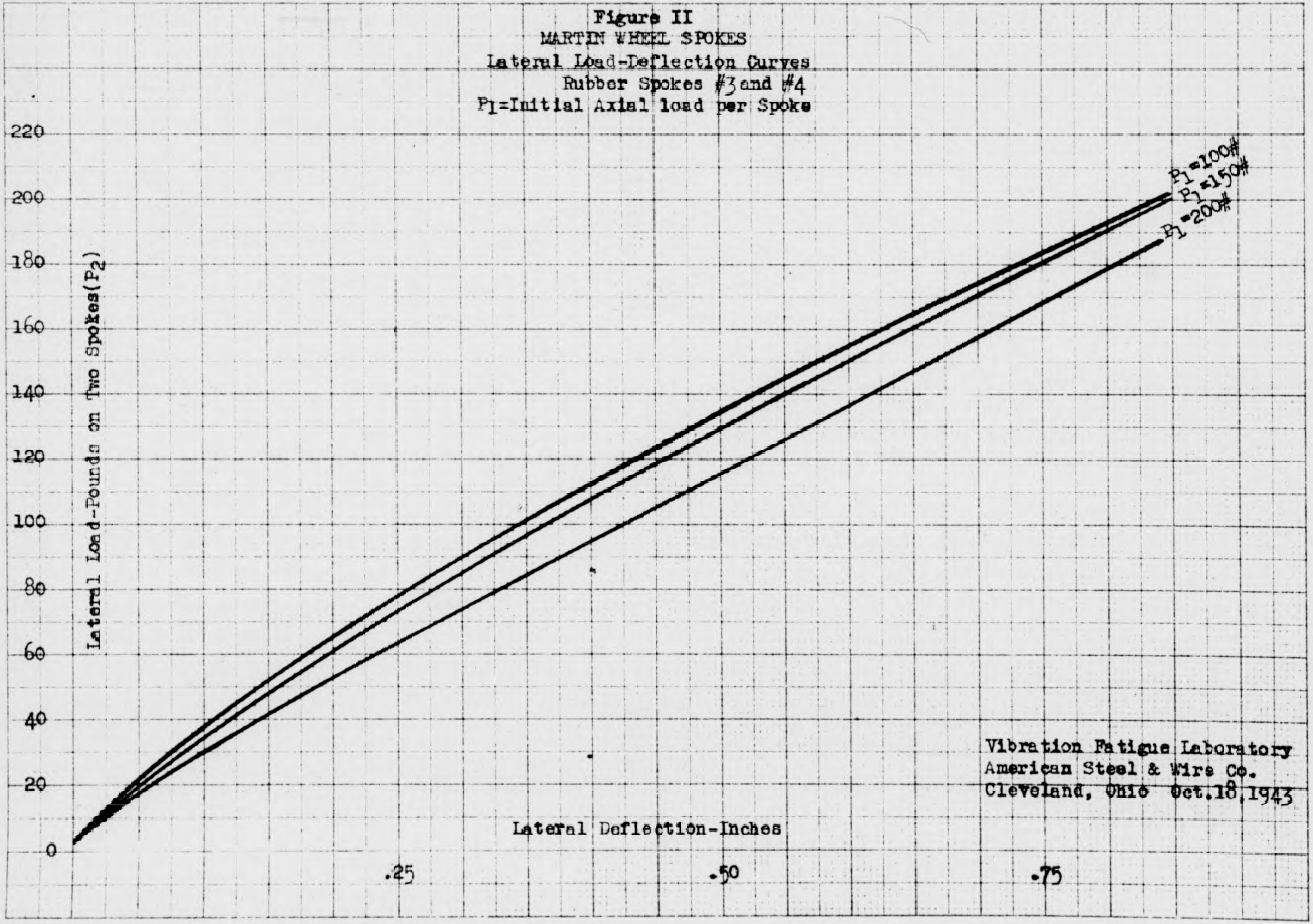


Figure II
MARTIN WHEEL SPOKES
Lateral Load-Deflection Curves
Rubber Spokes #3 and #4
P1=Initial Axial load per Spoke
Lateral Load-Pounds on Two Spokes(P2)
Lateral Deflection-Inches
220
200
180
160
140
120
100
80
60
40
20
0
.25
.50
.75
P1=100#
P1=150#
P1=200#
Vibration Fatigue Laboratory
American Steel & Wire Co.
Cleveland, Ohio Oct.18,1943

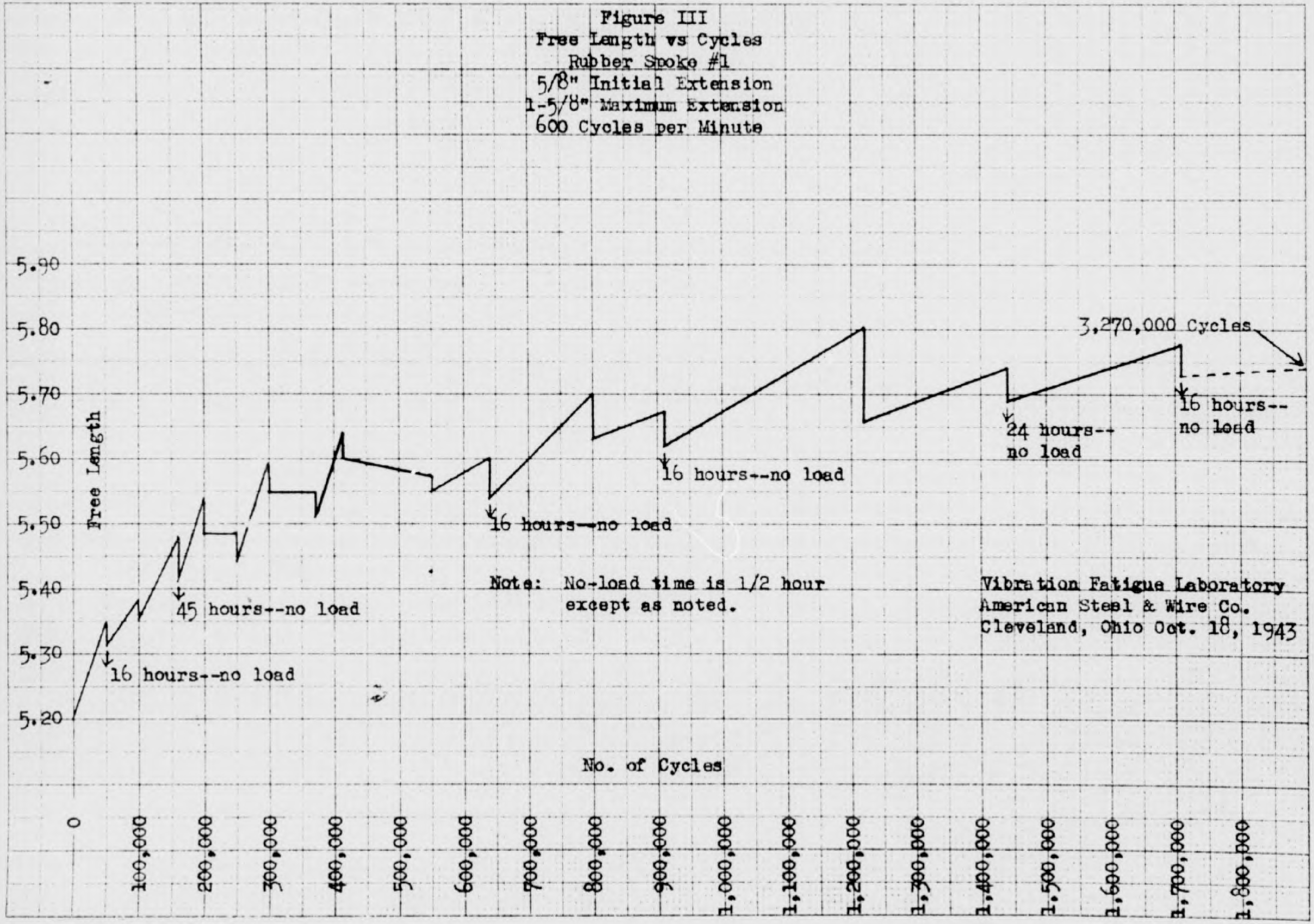
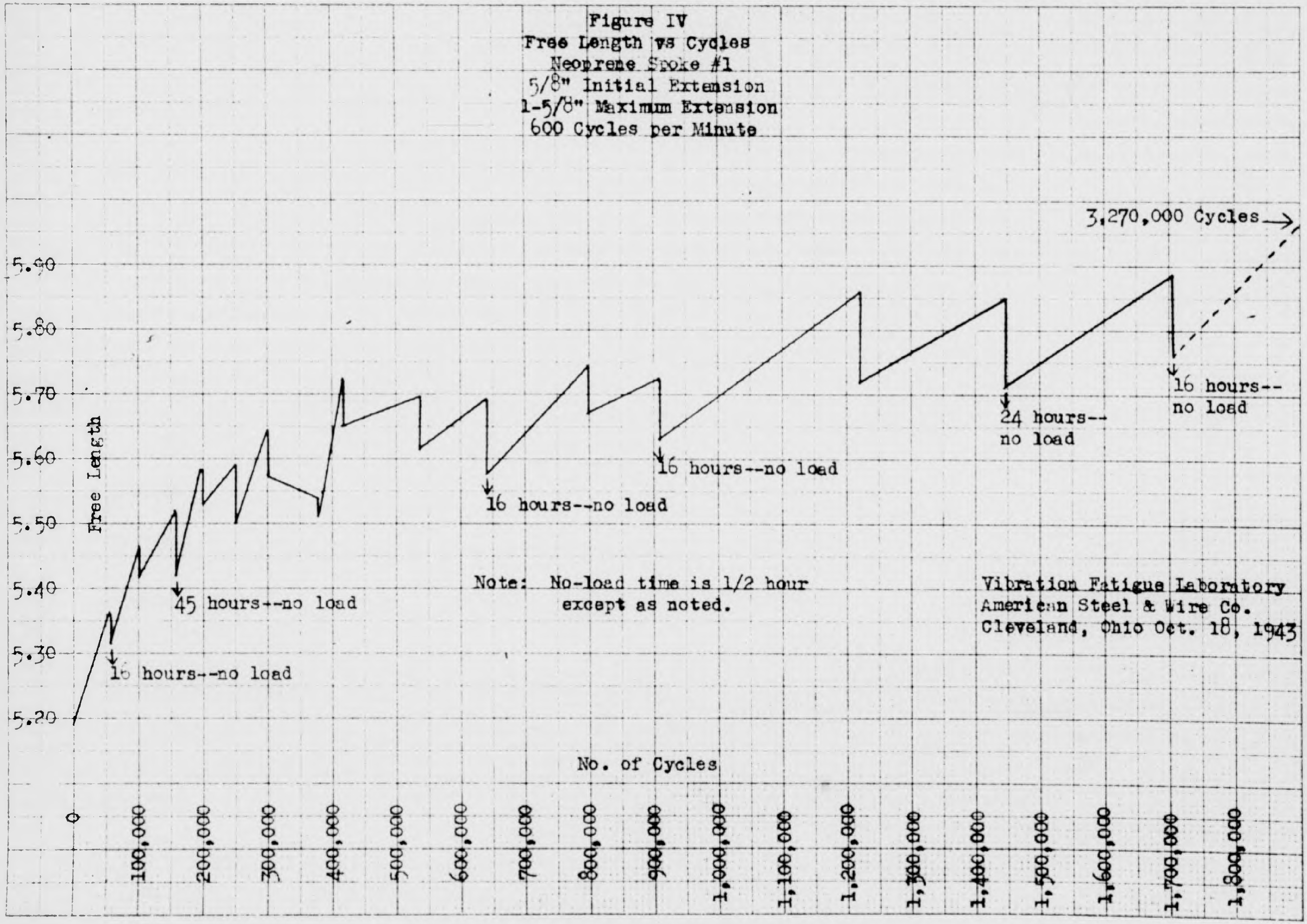


Figure III
Free Length vs Cycles
Rubber Spoke #1
5/8" Initial Extension
1-5/8" Maximum Extension
600 Cycles per Minute
Free Length
5.90
5.80
5.70
5.60
5.50
5.40
5.30
5.20
No. of Cycles
0
100,000
200,000
300,000
400,000
500,000
600,000
700,000
800,000
900,000
1,000,000
1,100,000
1,200,000
1,300,000
1,400,000
1,500,000
1,600,000
1,700,000
1,800,000
16 hours--no load
45 hours--no load
16 hours--no load
16 hours--no load
24 hours--no load
16 hours--no load
3,270,000 Cycles
Note: No-load time is 1/2 hour except as noted.
Vibration Fatigue Laboratory
American Steel & Wire Co.
Cleveland, Ohio Oct. 18, 1943

Figure IV
Free Length vs Cycles
Neoprene Spoke #1
5/8" Initial Extension
1-5/8" Maximum Extension
600 Cycles per Minute



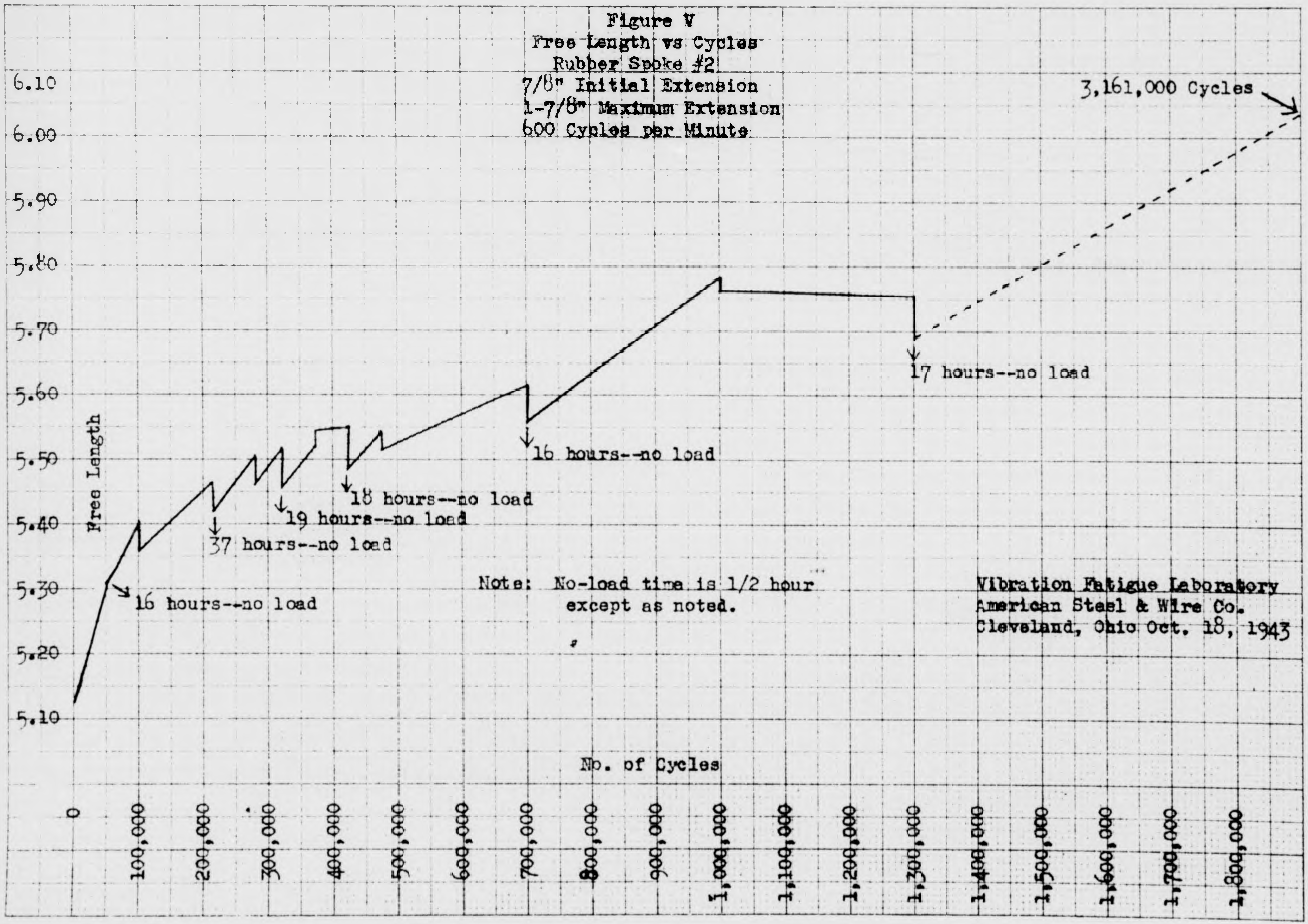


Figure V
Free Length vs Cycles
Rubber Spoke #2
7/8" Initial Extension
1-7/8" Maximum Extension
600 Cycles per Minute
3,161,000 Cycles
6.10
6.00
5.90
5.80
5.70
5.60
5.50
5.40
5.30
5.20
5.10
Free Length
16 hours--no load
37 hours--no load
19 hours--no load
18 hours--no load
16 hours--no load
17 hours--no load
Note: No-load time is 1/2 hour
except as noted.
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No. of Cycles
0
100,000
200,000
300,000
400,000
500,000
600,000
700,000
800,000
900,000
1,000,000
1,100,000
1,200,000
1,300,000
1,400,000
1,500,000
1,600,000
1,700,000
1,800,000

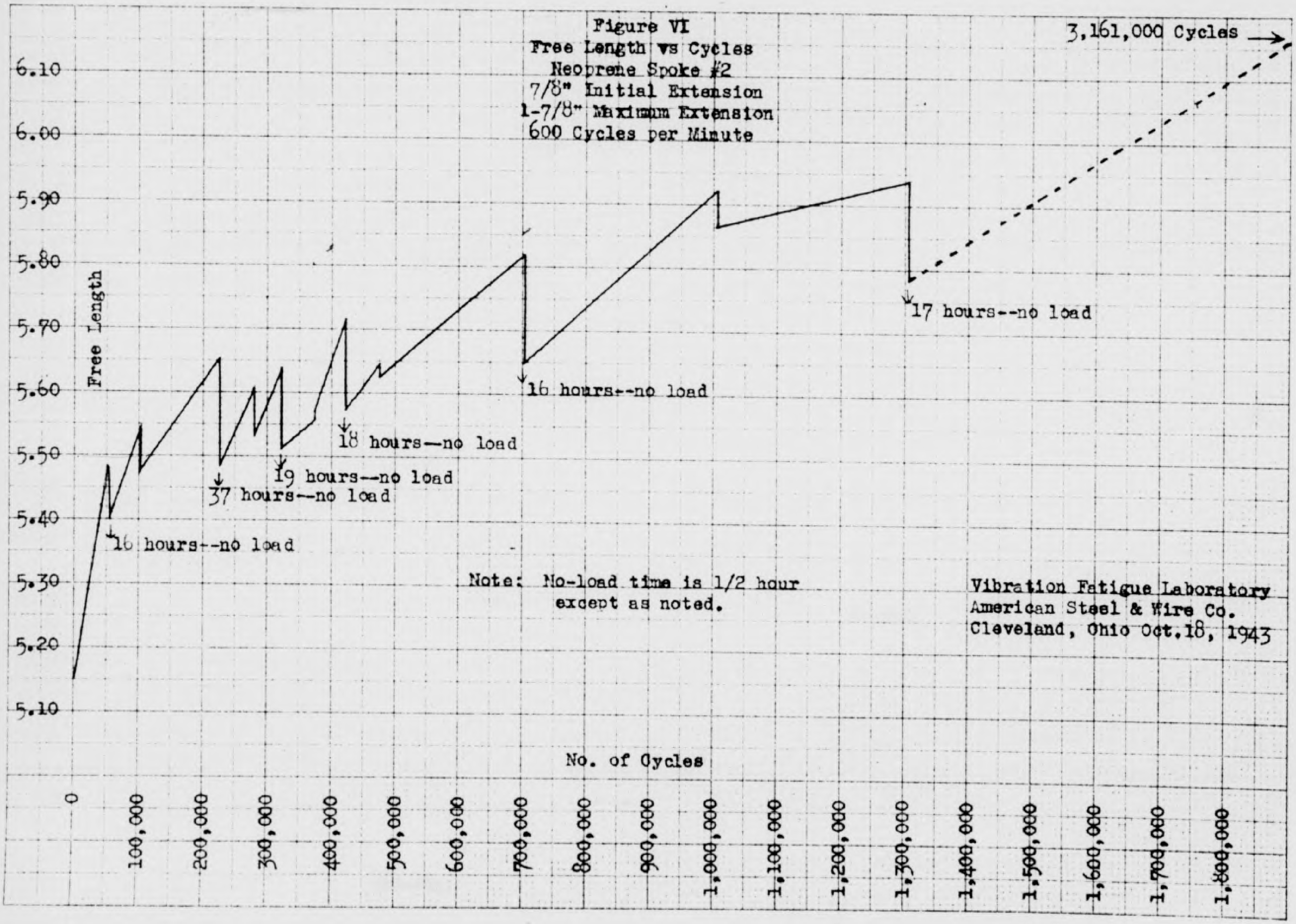
Figure VI
Free Length vs Cycles
Neoprene Spoke #2
7/8" Initial Extension
1-7/8" Maximum Extension
600 Cycles per Minute
3,161,000 Cycles
Free Length
6.10
6.00
5.90
5.80
5.70
5.60
5.50
5.40
5.30
5.20
5.10
16 hours--no load
37 hours--no load
19 hours--no load
18 hours--no load
16 hours--no load
17 hours--no load
Note: No-load time is 1/2 hour except as noted.
Vibration Fatigue Laboratory
American Steel & Wire Co.
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No. of Cycles
0
100,000
200,000
300,000
400,000
500,000
600,000
700,000
800,000
900,000
1,000,000
1,100,000
1,200,000
1,300,000
1,400,000
1,500,000
1,600,000
1,700,000
1,800,000

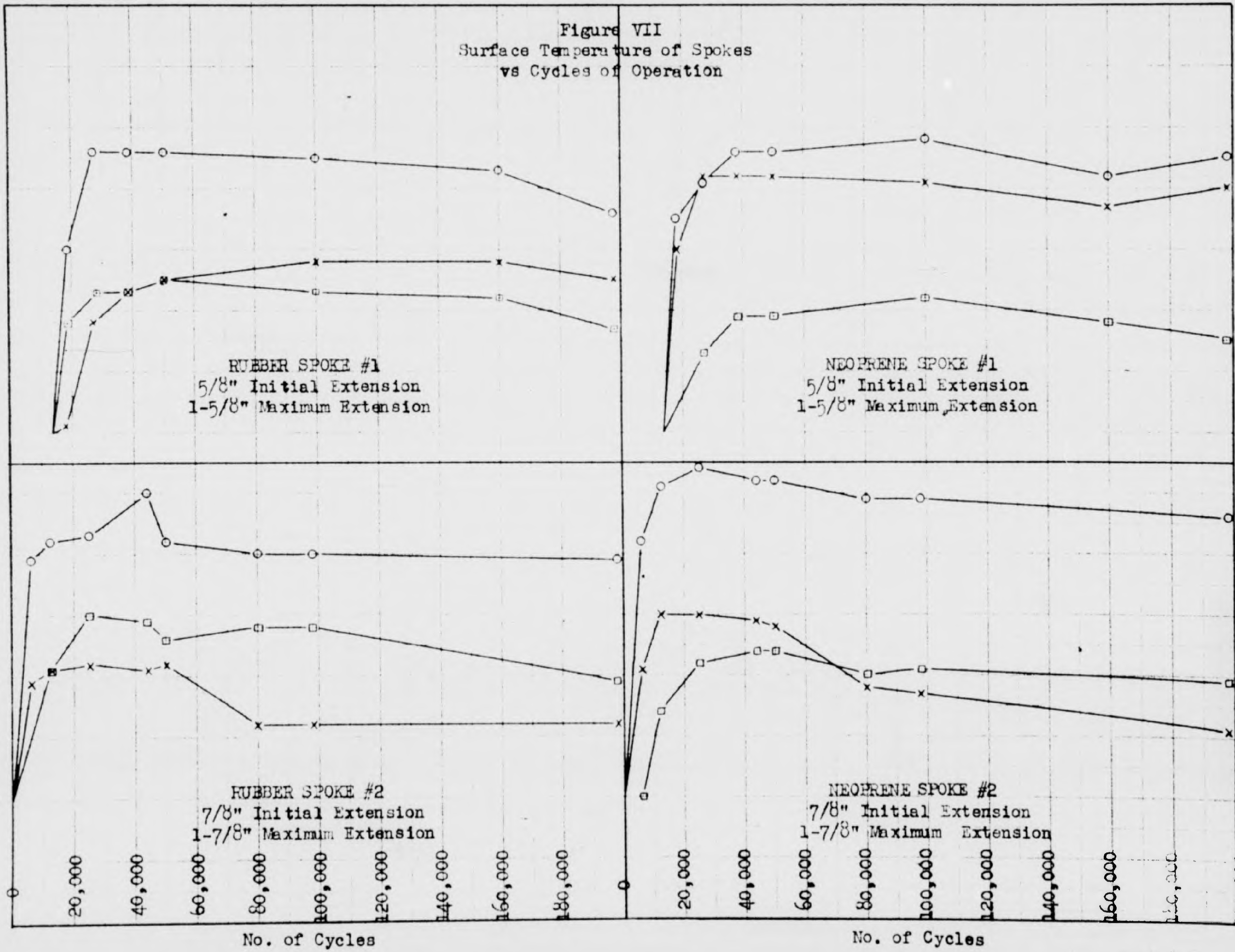

Figure VII
Surface Temperature of Spokes
vs Cycles of Operation

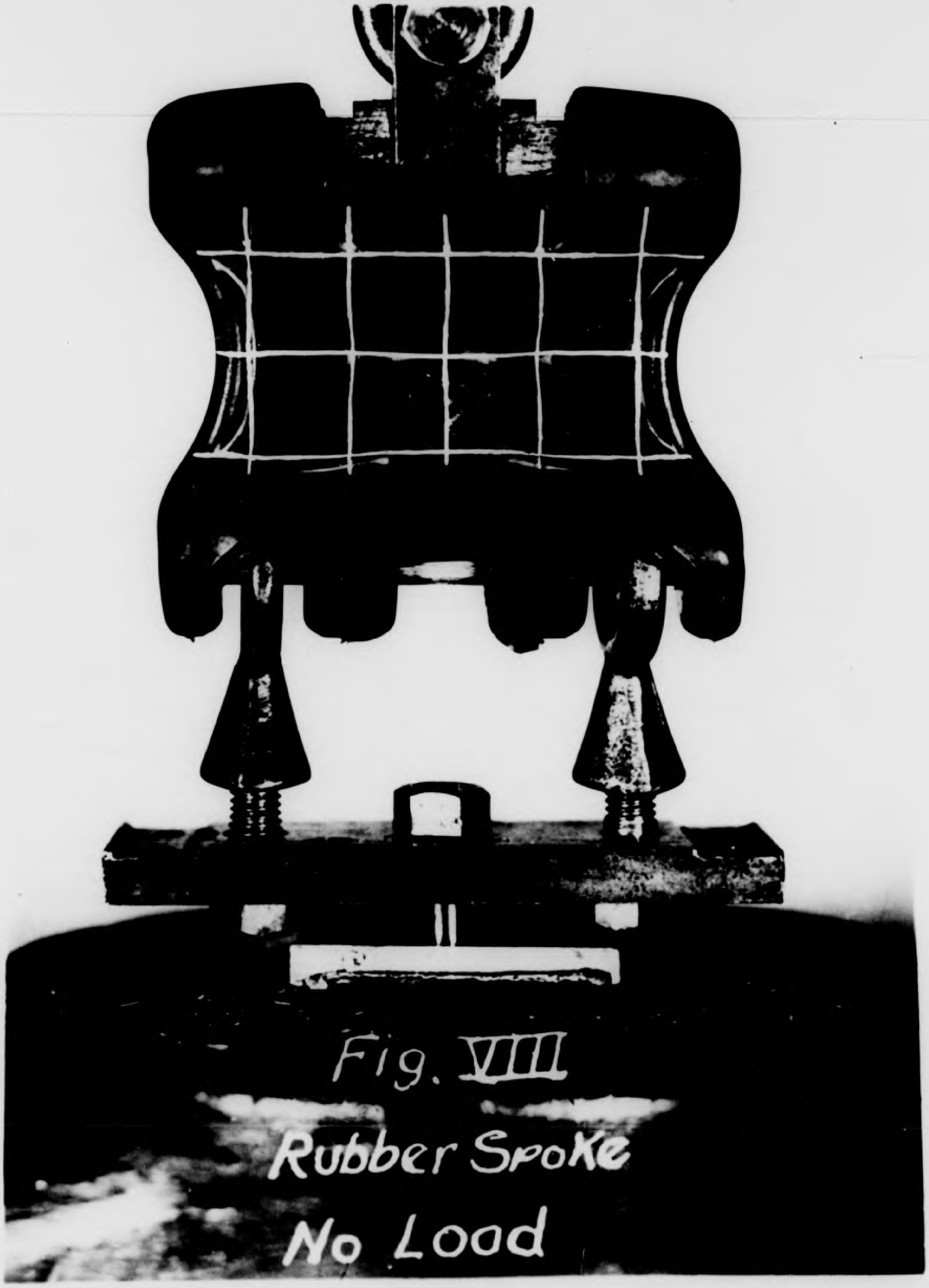

Fig. VIII
Rubber Spoke
No Load

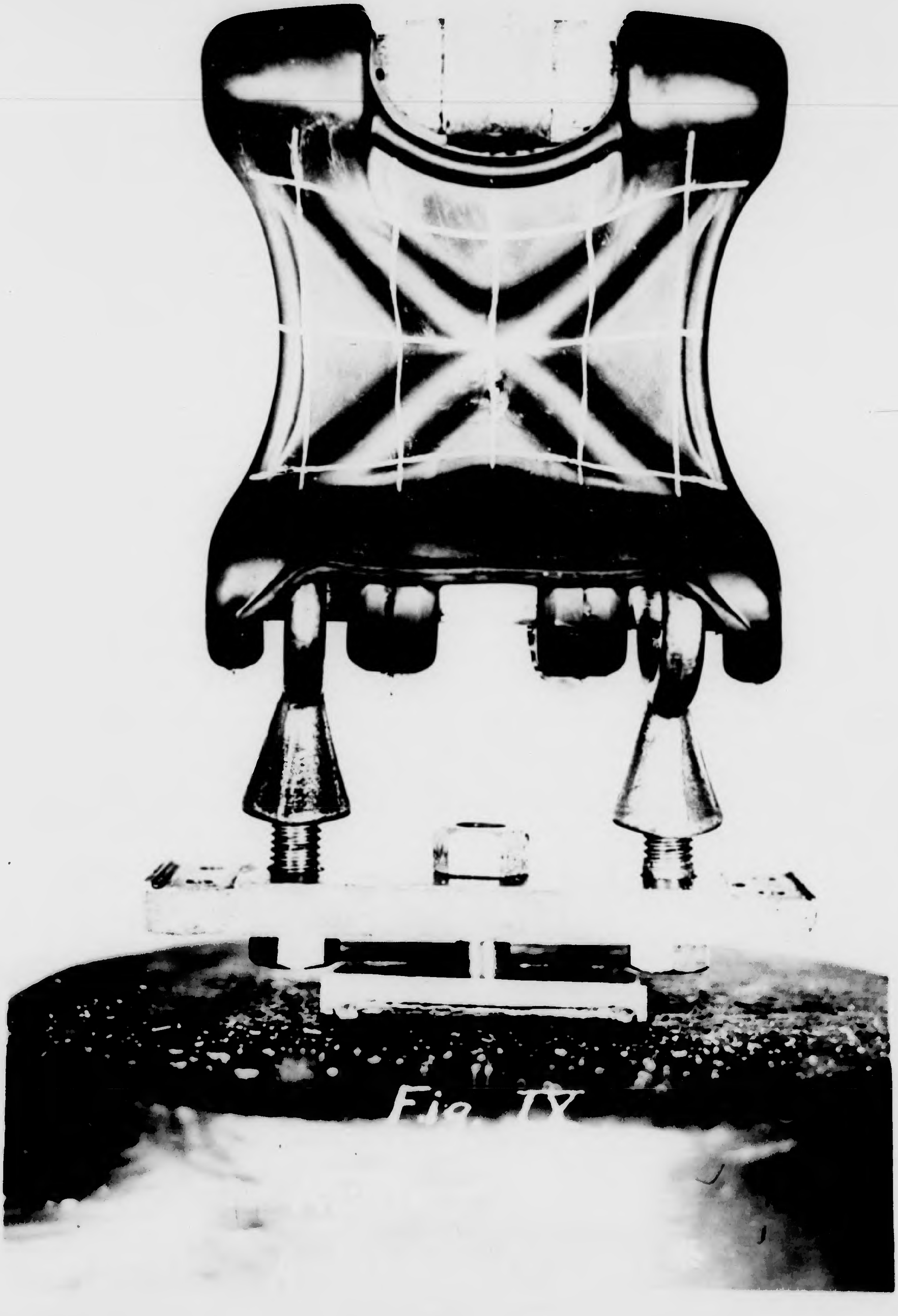

Fig. IX

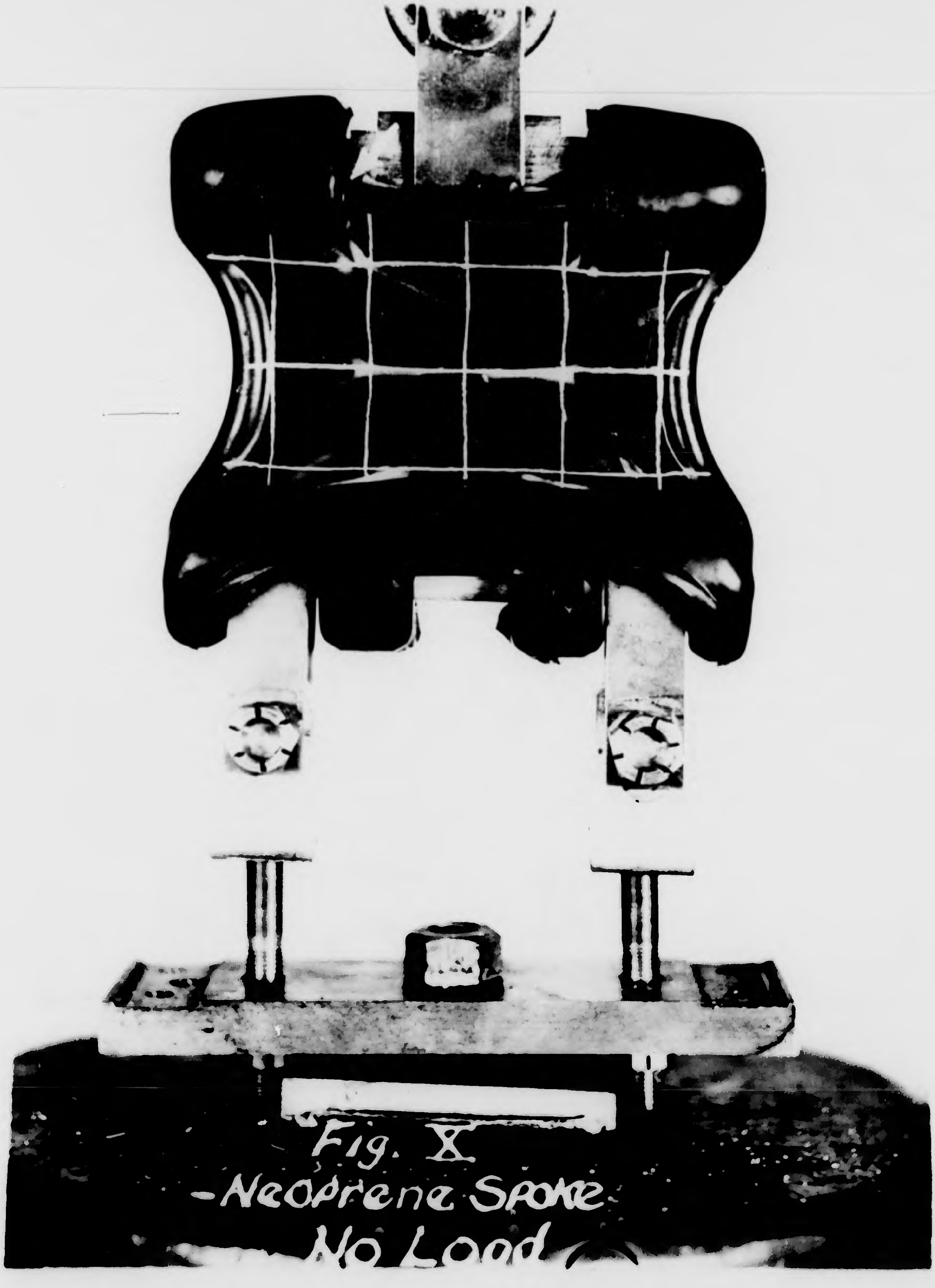

Fig. X
-Neoprene Spoke-
No Load

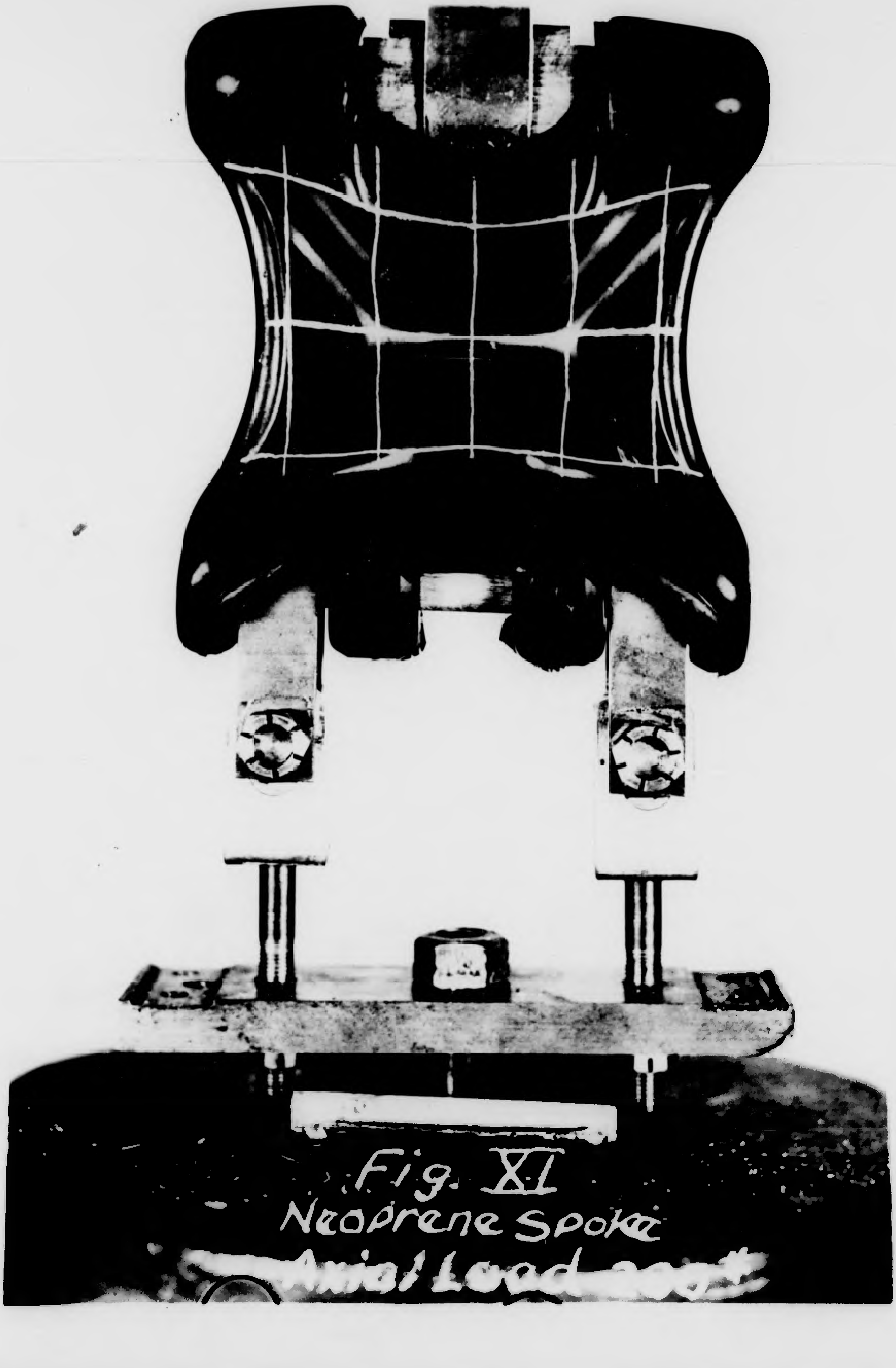

Fig. XI
Neoprene Spoke
Axial Load [illegible]

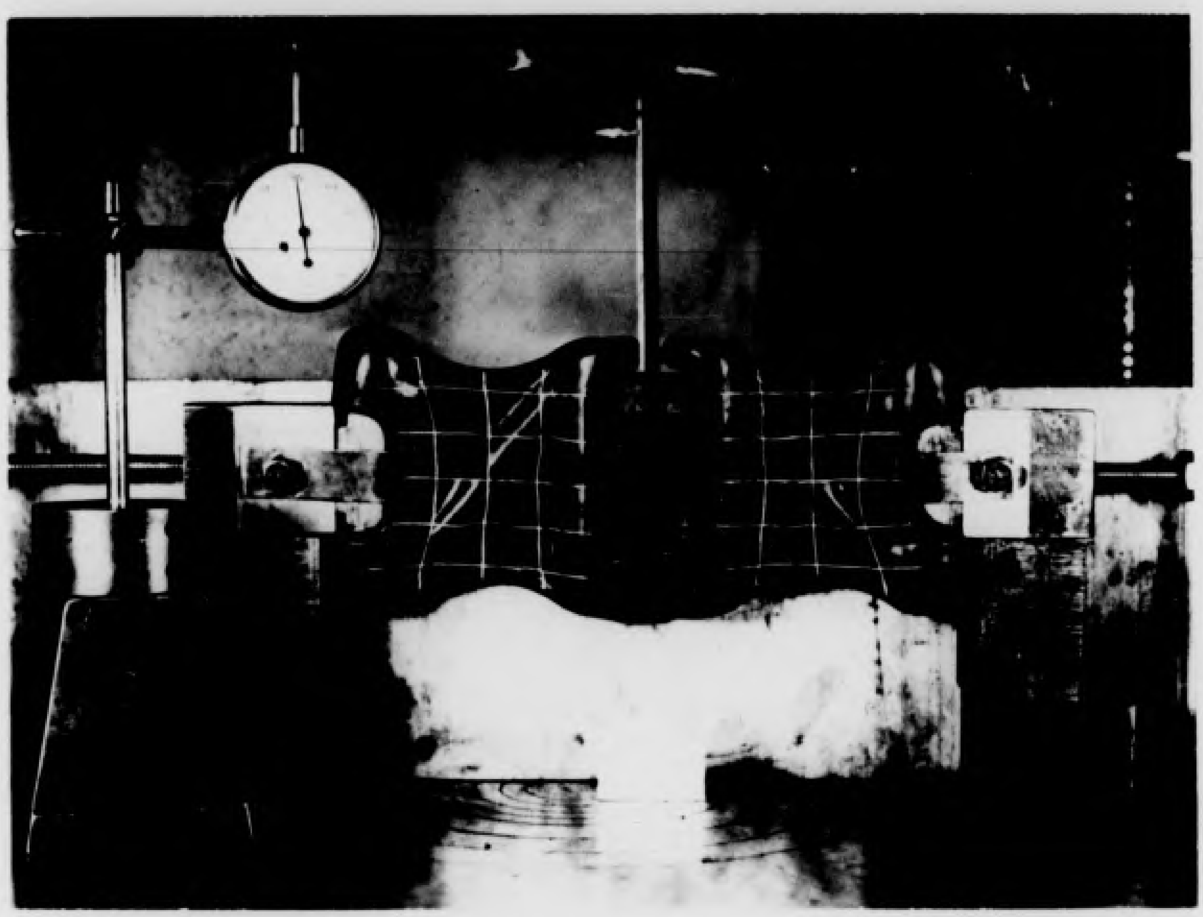

Figure XII. Lateral load test apparatus.
Axial load of 200#, lateral load zero

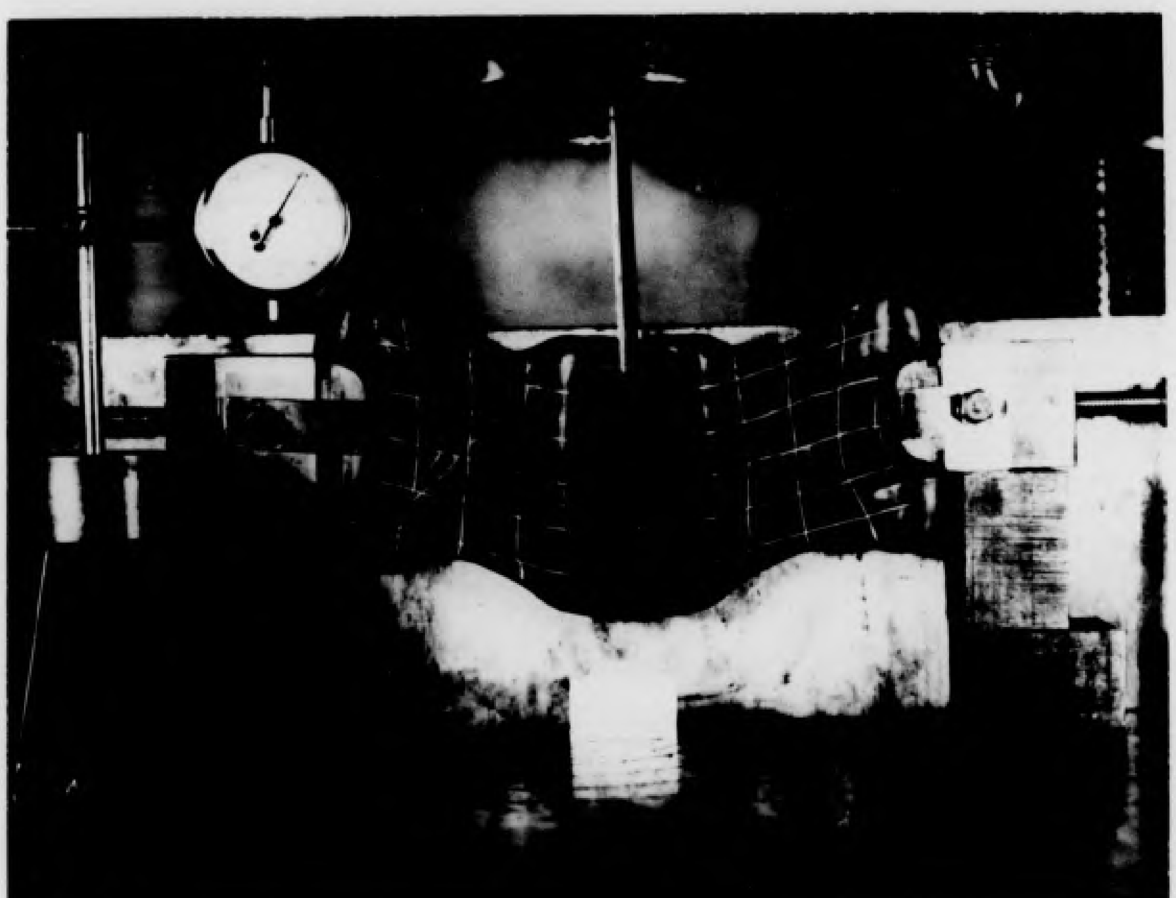

Figure XIII. Lateral load test apparatus.
Axial load 200#, lateral load 250#

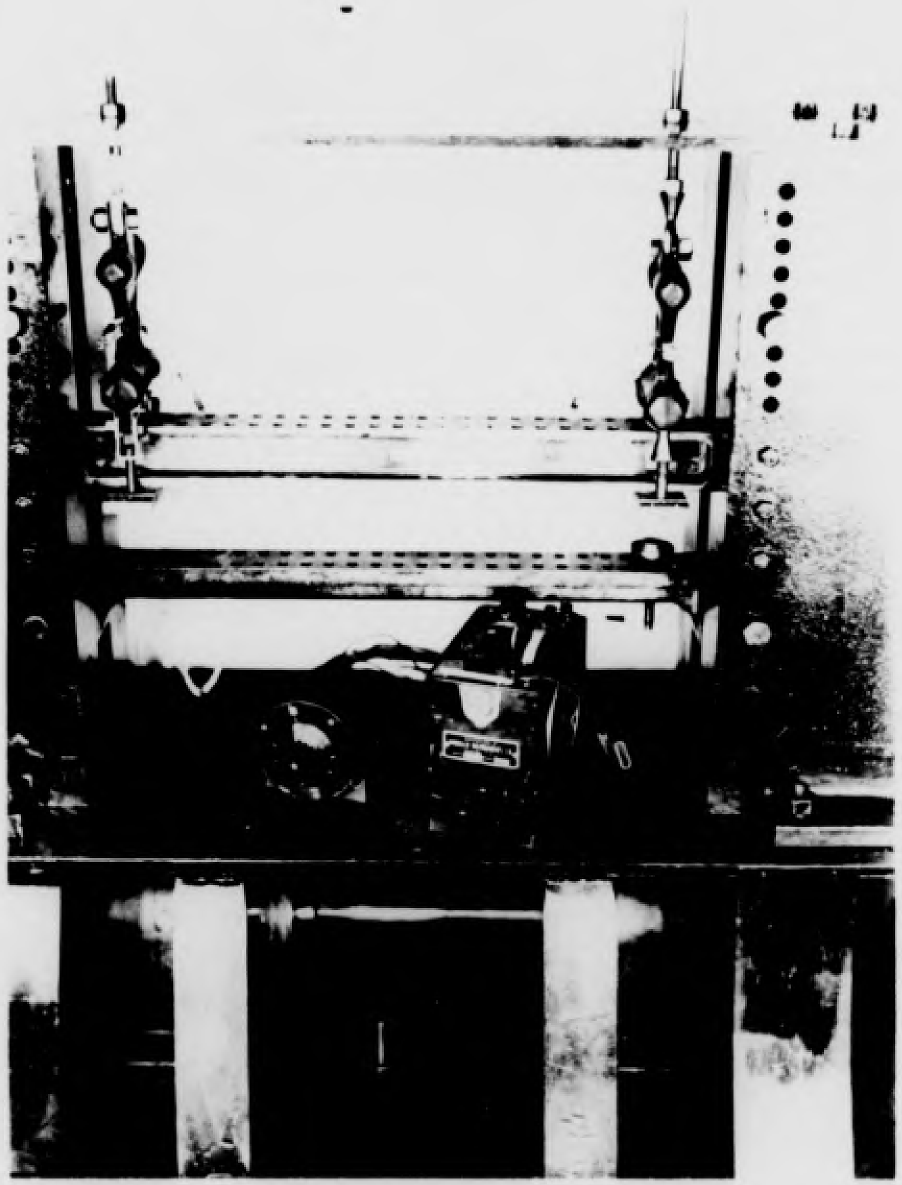

Figure XIV. Apparatus for repeated Cycle loading test, showing potentiometer, selector switch, and thermocouples attached to neoprene and rubber spokes.

Figure XV. Close-up view of rubber spoke showing relative positions of attached thermocouples.